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Discovery and Innovation in Basic Research

JUSTIN KOO, IN-SPACE PROPULSION BRANCH TECHNICAL ADVISOR
AEROSPACE SYSTEMS DIRECTORATE, 21 MAY 2019

Basic Science: Discovery AND Innovation

- **Discovery** – solutions looking for problems
 - I'm not sure what it'll do, but I know it will be impactful across many areas
 - More brand-new research / less leverage of existing research from other disciplines
- **Innovation** – solutions inspired by problems
 - I know there's a problem, what is the optimal way to tackle it
 - Less brand-new research / more leverage of existing research from other disciplines
- AFOSR is constantly trying to find appropriate equilibrium between Discovery and Innovation
 - No clear delineation → reflects direct inputs from PO and AFOSR leadership, indirectly from labs
- Common thread on successful basic research efforts, both at AFOSR and AFRL, involves both excellent technical effort AND clear communication on the impact

You must constantly communicate the impact of your research, both short- and long-term!

Ways to define impact (1)

- **Enabling** technologies open new possibilities

Examples include:

- Brand new thruster/power concepts (e.g.. exploiting new control strategy to improve performance)
- New diagnostic / simulations to study previously inaccessible (but critical) regions
- Breakthroughs in material / manufacturing

Potential impacts include:

- Game-changing performance/cost beyond present technology options
 - Opening up new application areas outside of space (especially for power technologies)
-
- Do not assume that government agencies understand why these enabling technologies are so important
 - You **will** be asked many times to explain the relevance of your work – because “fundamental” is very difficult to advocate at higher levels

Need to be explicit about potential impacts

Ways to define impact (2)

- **Accelerating** technologies increase the rate of TRL enhancement

Examples include:

- Data fusion / assimilation strategies to enhance value of multiple data streams (experimental / low/hi fidelity numerical / theory)
- Research approaches that materially expedite time-to-solution (faster diagnostics / identification of lower-dimensional manifolds and redundant data)
- Methodologies to rapidly and confidently explore operating manifold

Potential impacts include:

- Improved reduced order models and, more importantly, improved confidence in range of applicability
→ Enables faster systems engineering design cycles
- Identifying potential pathways towards real-time integrated health monitoring / integrated health management
→ Increased confidence in schedule for future TRL enhancement

Strong DoD interest in how to transition tech from the lab to flight faster

Navigating government review process

- Well-defined basic research should not be adversely affected by government review
 - Should always point to potential thruster improvements, but focus research plan on developments to:
 - Understanding of underlying physics
 - Impact/relevance of new diagnostics
 - Validated theory and model development
 - Accelerated learning strategies
 - Still need to tie research back to the transition impacts described in the first two slides
- We will be discussing broad tech areas/challenges that we see affecting DoD future space propulsion systems
 - We will advocate for these at an appropriate distribution level
- We have missed critical tech challenges that will both enable and accelerate technology development
 - You are going to have to work harder to elaborate on the transition impacts

Your Research → Technology Challenge → Transition Impact

Future of DoD Space Enterprise

Thompson: AFSPC Will Use Mega Constellations « Breaking Defense ...

<https://breakingdefense.com/2019/04/thompson-afspc-will-use-mega-constellations/> ▼

1 day ago - WASHINGTON: Air Force Space Command's vice commander says he is "highly confident" that large Low Earth Orbit constellations (known in DoD be part of the future military space architecture. "We will be using p

Missing: ~~raymond~~ | Must include: [raymond](#)

- Leverage proliferated LEO – incredibly fast and efficient way to insert new space capabilities (SDA)

Wilson: DoD Study Finds 'Exquisite' Satellites Still Needed « Breaking ...

<https://breakingdefense.com/.../wilson-dod-study-finds-exquisite-satellites-still-needed/> ▼

Apr 9, 2019 - While the Air Force is "funding development of **LEO** and ... acquisition authority for next-generation space systems to the future Space Development ... more enthusiastic than Wilson about the chances for "**proliferated LEO**" to ...

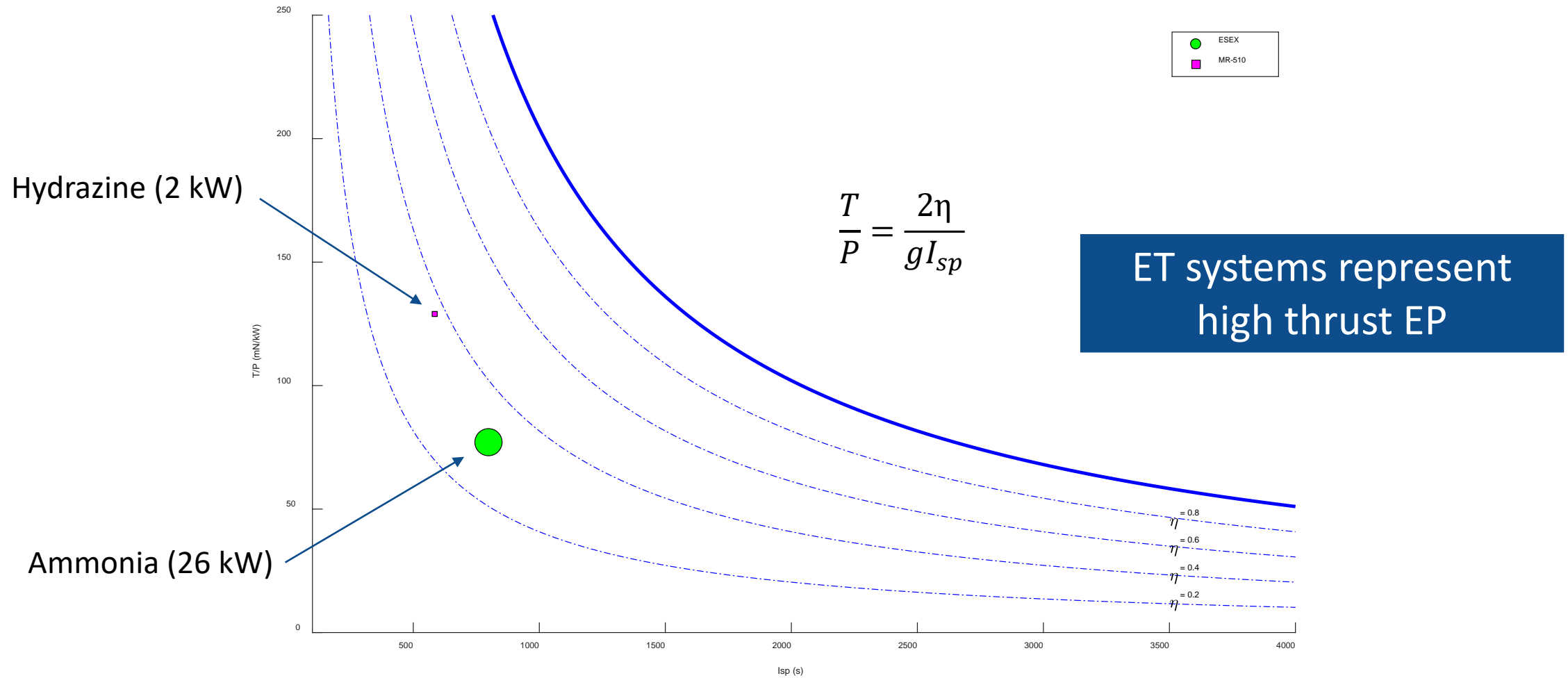
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- Accelerate traditional DoD space constructs (SMC 2.0)

from google search – 01 May 2019

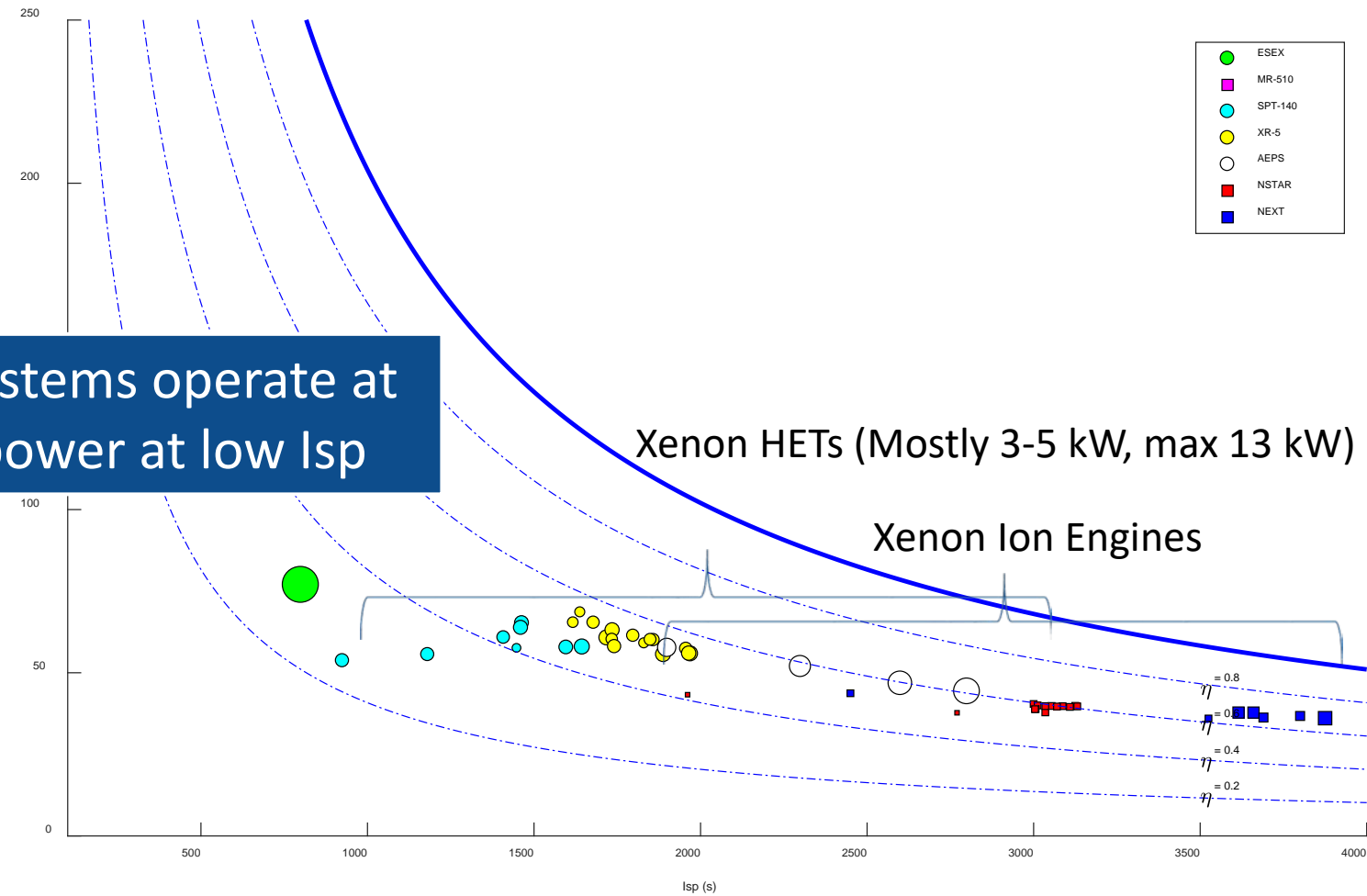
Only consistent message is to expedite transition of tech from the lab to flight

Early generation EP

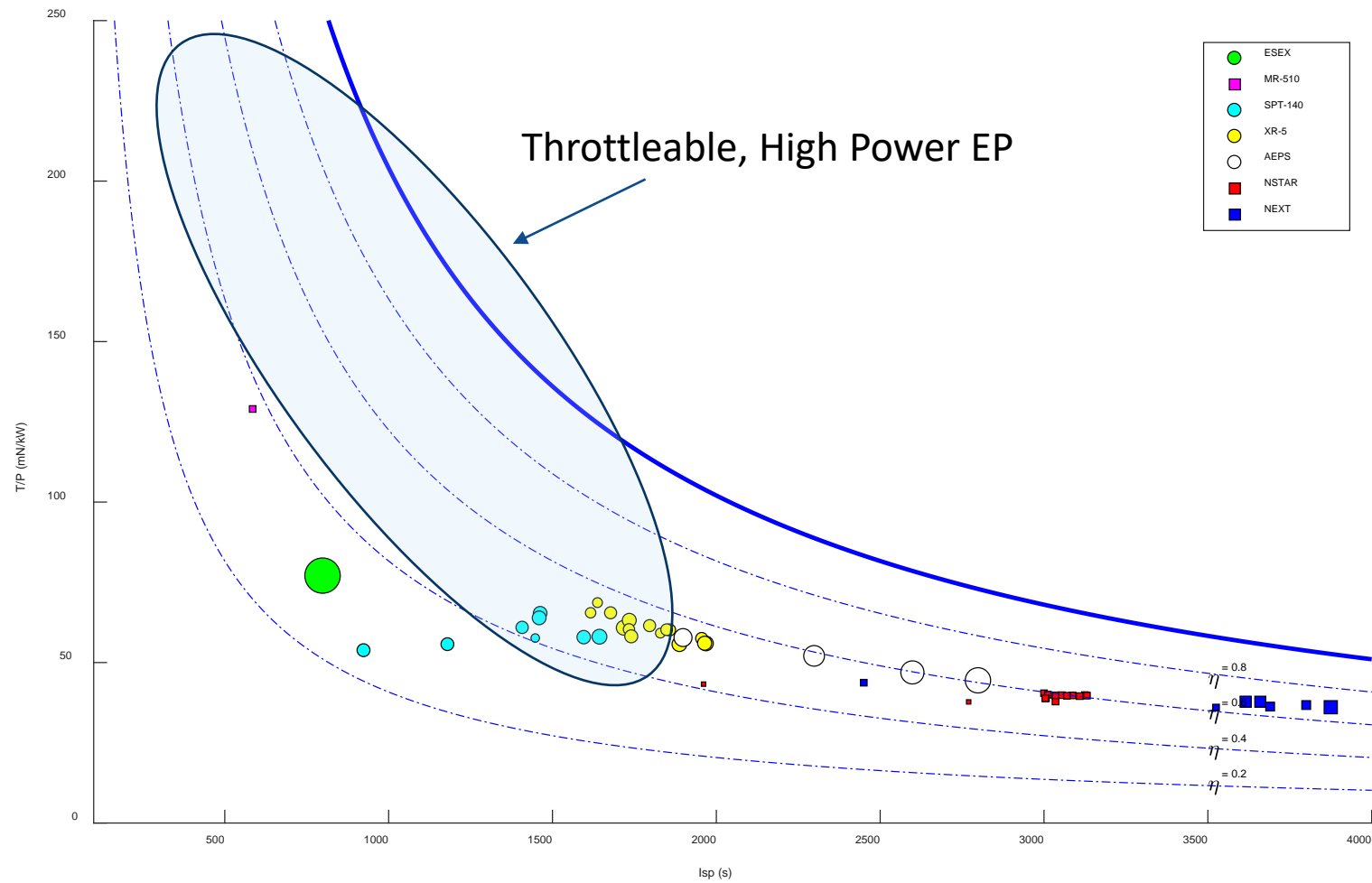


Present generation EP

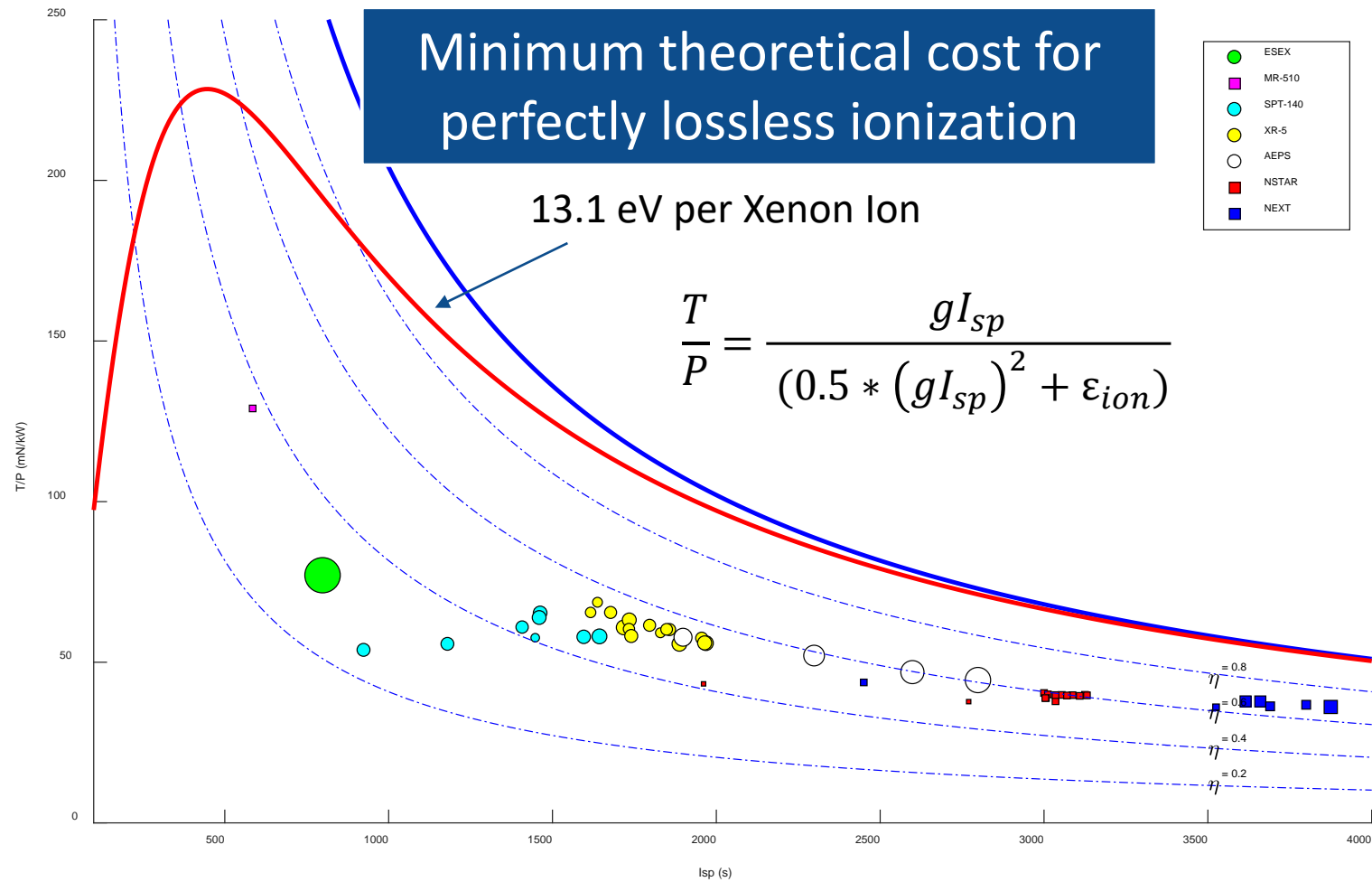
HET systems operate at low power at low I_{sp}



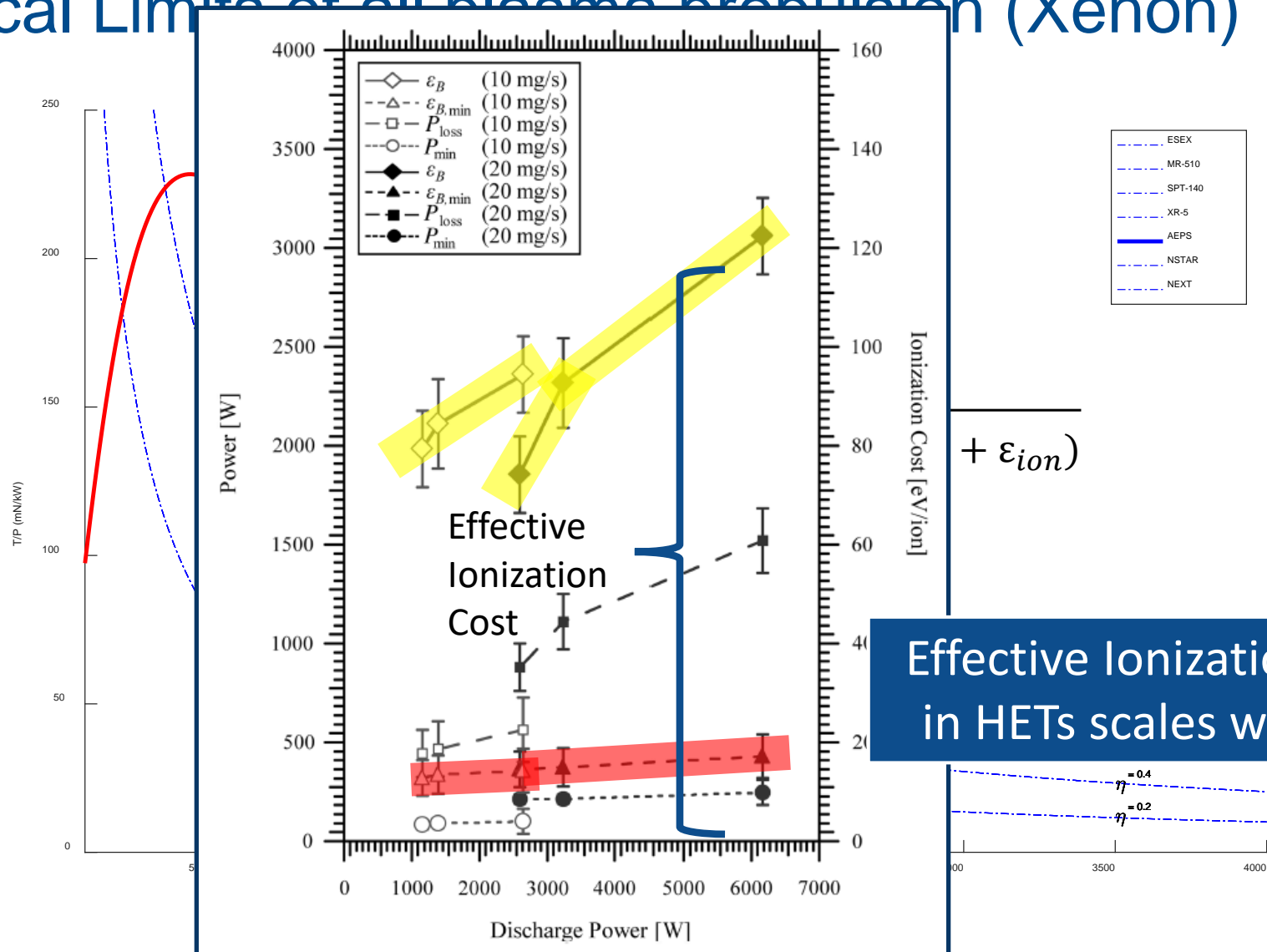
Next-generation EP



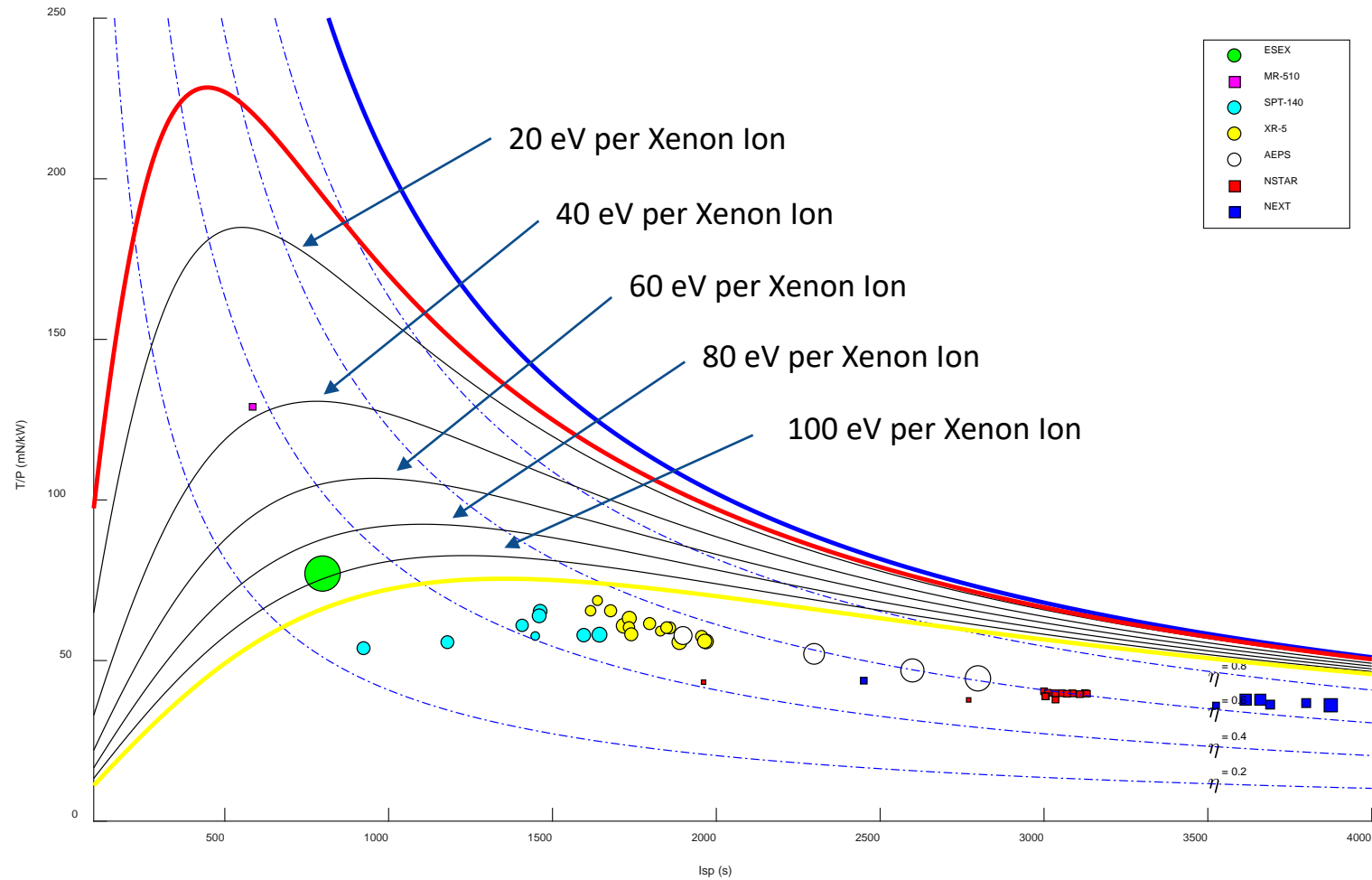
Theoretical Limits of all plasma propulsion (Xenon)



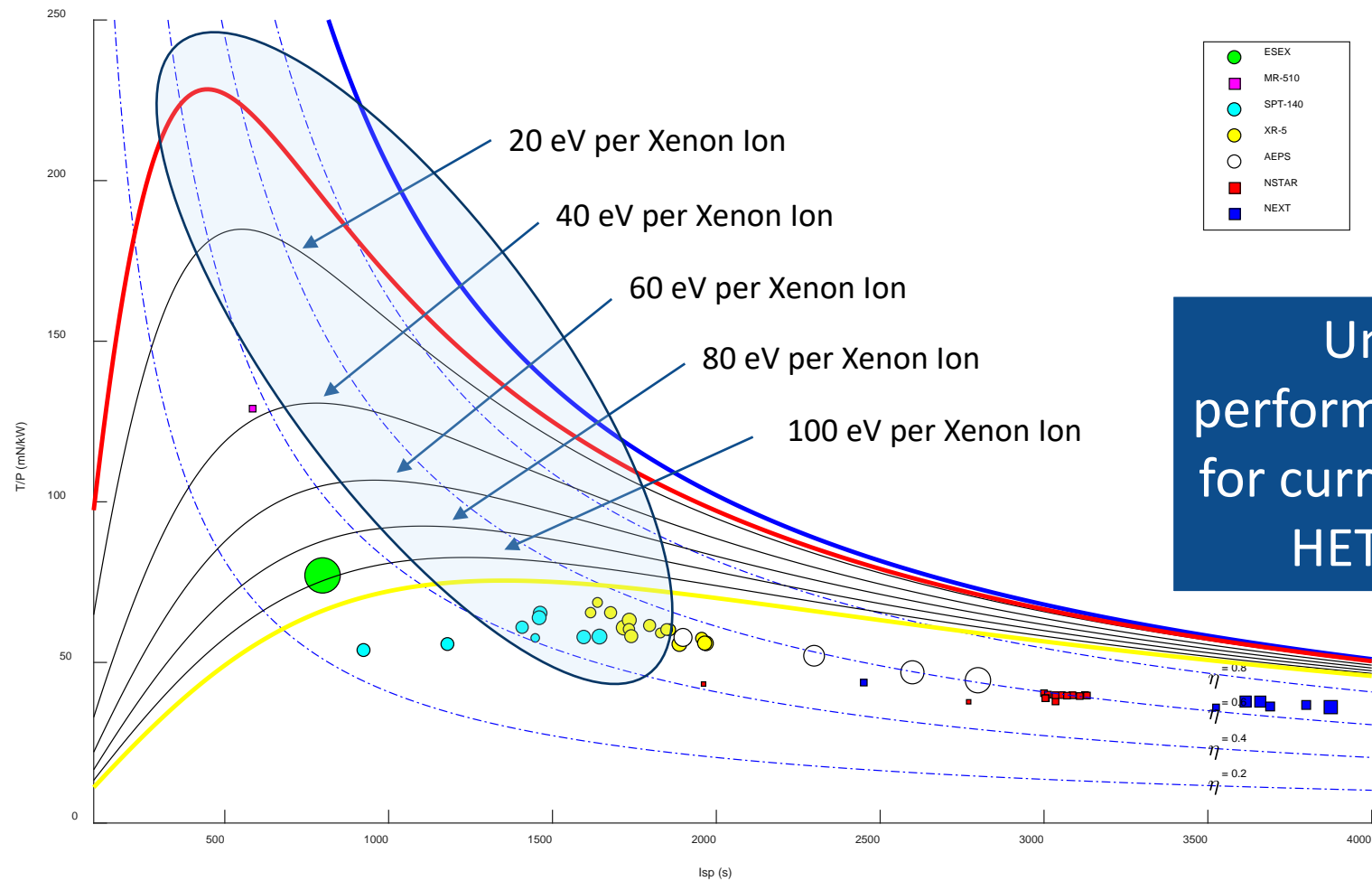
Theoretical Limits of all plasma propulsion (Xenon)



Practical limits on next-generation EP

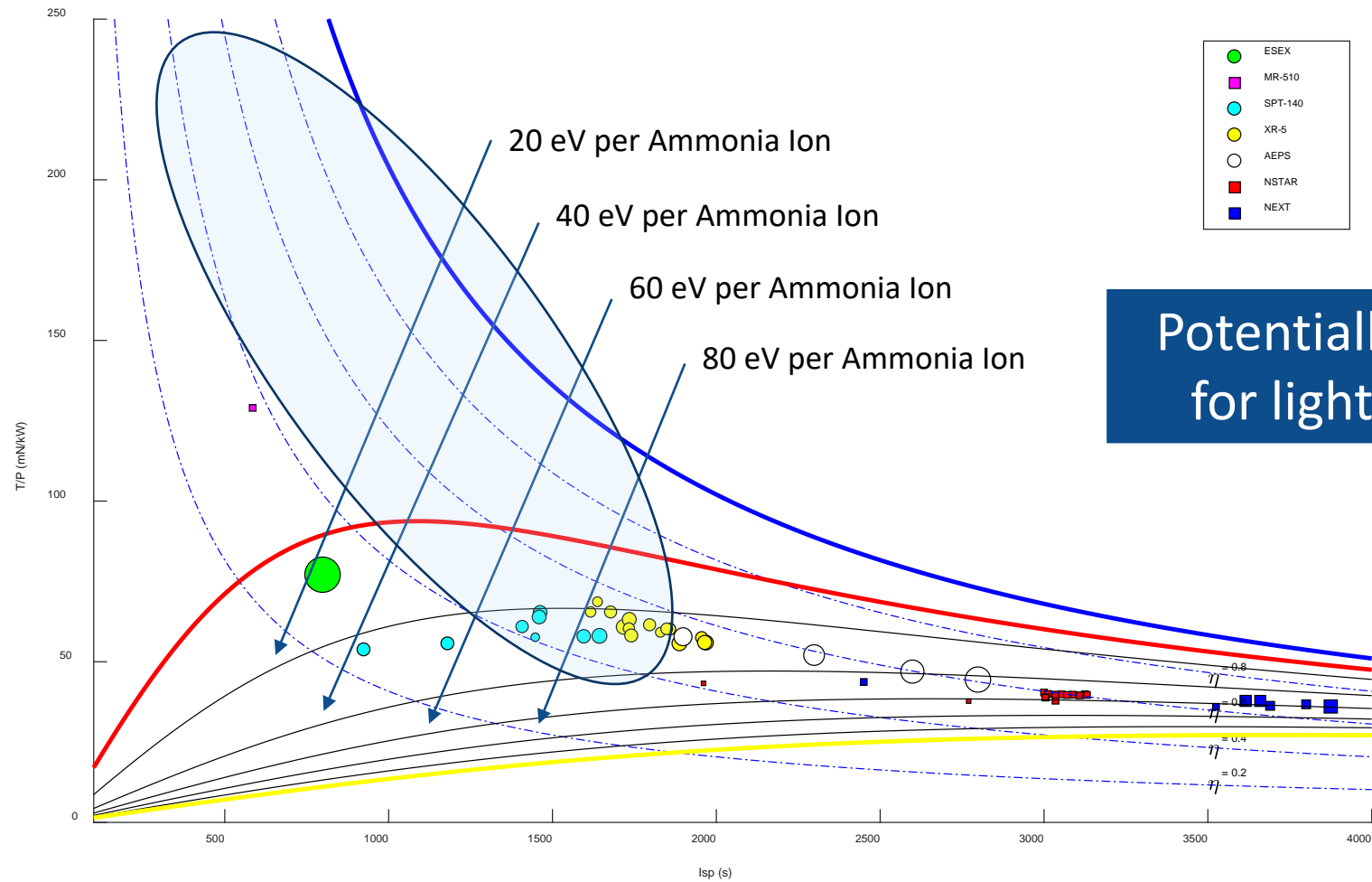


Next-generation EP (Xenon)



Unexplored
performance envelope
for current generation
HETs is limited

Next-generation EP (Ammonia)



Potentially even worse
for light propellants

Backup Slides

Enabling throttlable, high efficiency, high thrust EP

Goal: Throttleable (<1000-2000 s), high efficiency EP

- Transient power inputs up to an order of magnitude higher than current SoA

Potential Approaches

- Non-thermal ionization approaches; leveraging transient generation / rapid acceleration (pulsed systems); avoid ionization altogether (Ionic Liquids)

Challenges

- Ionization losses / acceleration mechanism closely linked – how can we isolate and study effects?
- In-lieu of complete thruster testing, how can we reasonably discuss cost per ion?
- Optimization of dynamic systems (e.g. changing pulse/current shapes) is very difficult

Reducing non-propulsive energy per ion is critical for high T EP operation